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CONCEPT MAPS IN PANAMANIAN CLASSROOMS: SEARCHING FOR PHOTOGRAPHS OF KNOWLEDGE

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Abstract: Concept Maps (Cmaps) were first conceived as a tool to represent and organize knowledge (Novak, 1984). Currently, this premise has been expanded due to the versatility of this tool, because Cmaps also provide for the construction of new knowledge at the individual level and in collaboration processes. It could be thought that Cmaps allow us to manage knowledge. Achieving that a Cmap reflects the knowledge of its builder is a task that requires time and dedication. This paper emphasizes strategies that, according to the experience gained in the classroom, could speed up the process of learning how to use the tool. By having greater skill in the use of the tool, it could be much easier to portrait the individual or collective knowledge in a Cmap. This paper presents the experience carried out in Panamá with three classrooms of 4TH graders in José María Torrijos elementary school; they were aided by their teachers and a group of facilitators from Conéctate al Conocimiento. The learners' training was carried out taking into consideration the necessity of using concept maps to "photograph" the different phases of a learning process, specifically for a Scientific Inquiry Project. The "photographs" of the process, as well as the results from the application of Cmaps are showcased in this paper. All this effort takes place in the search for the unification of two important proposals regarding educational matters in Panamá: Concept Maps and Scientific Inquiry Projects at the elementary school level. In Panamá, the concept map tool is being implemented massively in elementary schools through Conéctate al Conocimiento project, which is an initiative put forward by the Presidency Secretariat for Government Innovation (Tarté, 2006). At the same time, a science inquiry project named "Hagamos Ciencias" is being implemented, which belongs to the educational project area of another government entity, the National Secretariat for Science, Technology and Innovation. The present effort is concentrated in polishing the model and its application, as well as the way in which results are generated and processed. It is hoped that this model will be applicable and useful to others.

1 Introduction

Basically, every activity could imply some degree of learning. Although if what are intended to be achieved are pedagogical objectives, it is necessary to implement measures (pedagogical strategies) in order to achieve these objectives. For teachers to achieve this, it is necessary to resort to means that provide for the learner to "learn" that which is set as an objective. Currently Cmaps have become a good instance of a mean to learn. Since they were conceived by J. Novak in the early 70's, they have been present in every educational task. In Panama, Cmaps are implemented in elementary schools through the Conéctate al Conocimiento project (Tarté 2006). In the approach presented by the project, the issue of dexterity in constructing Cmaps is relevant. Beside this, some technological tools are also being implemented, such as the CmapTools software (Cañas, et al., 2004) and such tools are enhanced with Internet access in the schools. All this effort is towards the promotion on knowledge construction and collaboration in such construction. The aforementioned requires constant practice and feedback if what one pretends to achieve is that the tool becomes part of the individual, that means, that the individual can express through it without being limited by the tool, but quite the contrary, that the tool becomes a springboard to build, express and share his/her knowledge. This paper will show some ideas on how could dexterity in the construction of Cmaps be achieved. It is not a recipe book that can be applied in any context, but a concrete experience that allows us to guide and point out some key issues in school activities regarding the use of Cmaps. What is wished to point out is the objective of this paper: to use Cmaps as a tool to compare the knowledge previous to an inquiry experience versus what was learned after the inquiry experience was carried out. In this way, the Cmap is a useful tool for learners to represent and enrich their knowledge as well as to achieve the objective of this research by becoming portraits of knowledge.

1.1 Using Concept Maps to photograph Knowledge

Using a tool implies knowing how and for what it is used. Cmaps are not above this fact. It can't be expected that Cmaps reflect the knowledge of the person building it, if he or she doesn't know how to use the tool. The aforementioned seems obvious, however, the approaches on "how" one gets to have dexterity in the construction of Cmaps are diverse. Cmaps could be used to know, in an approximated fashion, what an individual knows. The aforesaid is true if and only if the person has dexterity constructing Cmaps. We will call "Faithful Cmaps"[1] those concept maps that are the closest approximation to what a person has in his or her mind

[1] When saying "faithful" it refers to the closest approximation that can be achieved between the Cmap and the knowledge of a person. Although what was just said presents an issue about the measurement of the approximation, it will suffice for now with the fact that Cmaps are a means of expression for an individual and we are interested in finding out if the person is expressing his/her ideas in an understandable fashion in the Cmap, and that is not the same as the individual expressing "all" his/her knowledge about a topic.

in regards to a topic. Faithful Cmaps would be those that reflect the knowledge of an individual free from the bias introduced by the use of the tool. A comparison could be made, in order to understand this idea, with written language; we are able to express ideas in written, only when we are proficient in it and consequently the "ideas that are thought" are equivalent to the "ideas that are written". Besides all these, Cmaps are a form of language and a means for dialogue at the same time. A dialogue that can be interpersonal (several individuals) and "intrapersonal" (inner dialogue, individual meta-cognition). That's why Cmaps can be seen as a "camera" that allows us to capture, in an increasing or decreasing degree, the knowledge that an individual has and how he/she has organized it. Obviously the quality of the photograph depends on the quality of the camera and the ability of the photographer. As a first step to approach the achievement of faithful Cmaps it has been proposed that the Cmaps keep a "propositional structure." This refers to place special emphasis in well defined concepts and that the relations (linking phrases) between concepts express clear ideas (Fig. 1) so as to have a "unit with meaning" or proposition; within this propositional structure, it is recommended the predominance of binary propositions (Miller, 2008), and not long lineal structures that are nothing more that the transcription of a sentence into a Cmap format.

a)

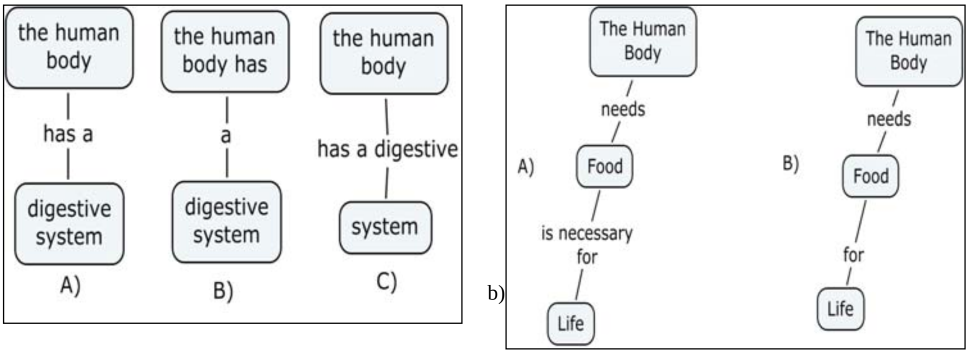

Figure 1. a) Three proposition A, B y C that when read express the same idea, however the disposition of the elements let us see that in A the idea is clear (concepts are easily recognizable and linking phrases are clear), on B the concept "the human body" is together with the verb "has", which shows that it is not completely clear how the concept is defined. In the case of C it could be seen that the concept "digestive system" has been segmented leaving "system" as the concept, in this case the concept is not accurate because it lacks its adjective "digestive" which appears in the link. It is important to point out that it is not only a matter of wrong spatial distribution of elements within the boxes corresponding to links and concepts, it is clear that the propositional notion has not being assimilated in cases B and C. b) Two sets of propositions, in case A it can be seen how starting from a concept (the human body, for instance) it arrives to another concept (food), when starting a new proposition from the arriving concept, this one becomes in the starting concept (food-----is necessary for-----life) and that process is repeated every time a new proposition is generating from a given concept. On the other hand, on B it is clear that if you read on "the human body needs food for life" it makes sense, however the isolated propositions are not clearly understood as in the case of A, all this mean is that in B case it is necessary to improve the skill in the construction of proposition. Notwithstanding that they try to express the same idea, on both cases, the set A has been elaborated propositionally, which is not the case of B.

2 Methodology

2.1 Searching for "Faithful Cmaps" to compare learning

The necessity of this research to make use of Cmaps to "photograph" different phases of a learning process comes into being within the framework of establishing a qualitative comparison of the Cmaps built by learners before and after they carry out the activities related to the "*Electrical Circuit"* Science Inquiry Project, which is part of the projects from Hagamos Ciencia.[2]. As an attempt to get closer to obtain faithful Cmaps the following actions were proposed: a) prior training for teachers and learners in the construction of Cmaps, b) "Translation mediation" on the part of facilitators during the Cmaps construction process by the learners (this term will be explained further on), and c) interviews to the learners after the construction on the Cmaps which were build before and after the Hagamos Ciencia experiments. Although we have focused on the learning process in an inquiry project, we consider that the following process could be applied in other scenarios; it may also be applied when some other kind of learning takes place.

a) Prior training for teachers and learners in the construction of Cmaps

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[2] Hagamos Ciencia, directed by Dr. María Heller, is part of the projects carried out by the Secretariat of Science, Technology and Innovation of Panamá (for further information www.senacyt.gob.pa)

The teachers' training took place before the learners' training, and it was carried out in a personalized manner (one to one facilitator-teacher). The learners' training was carried out in a collective manner with each classroom. Both training encompassed two phases: first, introduction to the tool and later reinforcement.
The introduction, for teachers as well as for learners, consisted in a session in which the basic notions for the construction of Cmaps were presented. This involved the construction of a Cmap. Each teacher constructed an individual Cmap. The learners' groups constructed each a collective Cmap in the board.[3] On both cases, emphasis was made in the propositional structure. The teachers were offered, additionally, strategies to help learners in the construction of Cmaps with good propositional structure. Some of the Cmaps built during this phase are shown on Fig. 2, on figure 2a is one Cmap made by one of the teachers and the on figure 2b is one Cmap made by the a group of learners.

The reinforcement consisted in the construction of Cmaps about the topics dealt with during classes. During this phase the teacher could reinforce his/her ability as a facilitator and the learners reinforced their abilities in the construction of Cmaps. This phase had an approximately duration of month and a half. All the Cmaps built from hence on were constructed in groups of 4 to 5 learners.

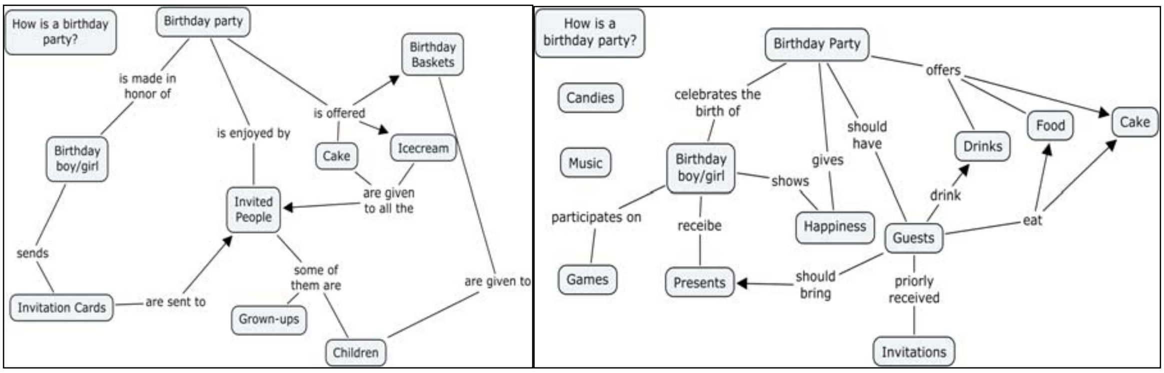


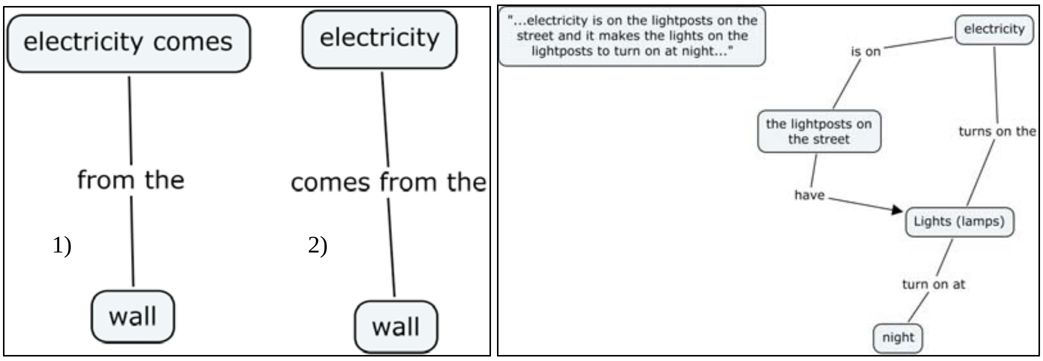
Figure 2. a) Concept map built by one of the 4th grade teachers of José María Torrijos elementary school, b) Concept Map built by a group of learners from 4th grade of José María Torrijos elementary school. (Transcribed from the board using CmapTools by one of the facilitators from Conéctate al Conocimiento)

b) "Translation mediation" during the Cmaps construction process

During the construction of all the Cmaps in this study, the facilitators of Conéctate al Conocimiento and the teachers from the school mediated in the process. The desire that the Cmaps reflect the ideas of the learners led the role of the mediator to consist on assuring that the propositional structure would be fulfilled in most of the cases. As it is shown further on in this article, this is of vital importance in order to interpret and compare the pre and post inquiry activity Cmaps. This is why it was intended that, if the learners could not structure the propositions correctly, the facilitators and the teachers would help them in this regard.

The abovementioned was carried out only with the structure of the idea, not in what it has to do with de validity of the idea; nor the undertone of the idea was judged. The team of learners gave their ideas; if it was necessary they were helped in structuring them as propositions without changing their original sense. This process was named translation mediation, because it is, literarily speaking, translating what is expressed naturally to a propositional structure. It was decided to follow this approach in order to enhance the Cmaps approximation to the learners' knowledge, all this with the objective of observing and comparing the previous knowledge versus the knowledge gained after the inquiry project activities. This approach was followed for the Cmaps constructed during the reinforcement as well as for the Cmaps constructed for comparison purposes. As an example illustrating this please refer to Fig. 3.

[3] To have the teachers starting the construction of their first training Cmap, the focus question was "How is a birthday party?" This question was chosen because, according to the experience gained during the Conéctate al Conocimiento workshops, it is the kind of focus question that lowers the topic profile (besides being fun) and it allows for the person to focus on the Cmap and not on the topic. Usually a complicated topic carries with itself "additional noise" at the moment of constructing Cmaps, although it is still needed to systematize the Conéctate al Conocimiento workshop experiences in order to give a more responsible statement in this regard.



a) b)

Figure 3. a) Example of propositions meditated by the facilitator, in this case it is not discussed with the learner the validity of the statement "electricity comes from the wall", the intervention was limited only to help structure the propositions correctly. In a-1 the first concept is "electricity" only while "comes from the" is the linking phrase and "wall" is the last concept. The facilitator helped only in improving the structure (a-2). b) The textual words expressed by the learners could be read on the upper right square. After mediating with the learners it could be translated to propositional structures.

c) Interviews to the learners after the construction of the Cmaps

The interviews were not made during the reinforcement sessions, they were only made after the construction of the pre and post experience Cmaps for Electrical Circuit and they were made with the purpose of collecting the learners ideas with a higher degree of detail. The interview process consisted on asking the group of learners to explain, in their own words, the ideas that were on their Cmaps. They were asked enhancement and inquiry questions, but not verification questions (Chacón, 2006) in order not to interfere with their previous knowledge, most of all in the case of the Cmaps previous to the experiences. It is important to point out how trained one must be in order to perform the interviews, above all for the ones directed to children between 9 and 10 years of age. The limitations presented when performing the interviews were due to the lack of this ability, because rehearsing helps improve the model and for a later application[4] the interview process could be refined so more details that do not appear on the Cmaps could be extracted from the learners.

2.2 Model Application: Photograph of before and after the Electrical Circuit experiences

The process was carried out in three fourth grade classrooms from the José María Torrijos elementary school; 4th grade A (with 25 learners), 4th grade B (with 29 learners) and 4th grade C (with 27 learners). These classrooms are attended by teachers Julio Vergara, Omaida Torres and Eirené Bravo respectively. Each classroom was divided in teams of 5 or 6 learners that totalled 15 teams (an average of five teams per classroom). Every team built a first Cmap previous to the experiment ($Cmap_{pre}$). The focus question for the $Cmap_{pre}$ was: What do you know about electricity? The learners were given a list of base-line concepts, that is, a "parking lot of concepts"[5] (PLOC) [6]. All of the concepts given to them formed part of the lesson to come on Electrical Circuits project. The time allowed for the construction was about an hour and a half for each team. All the necessary steps were taken in order to isolate as much as possible the teams from each other within a given classroom, although the physical size of the classrooms in function to the number of students prevented having an ideal isolation of the teams. The three facilitators from Conéctate al Conocimiento as well as the grade teacher offered mediation of the Cmaps construction. Considering the grade teacher as another facilitator, there were, in general four facilitators for five teams, almost a one-to-one (facilitator – team) attention. It should be stressed out that the mediation was carried out according to what was described before (translation mediation). Once the $Cmap_{pre}$ were finished, some of the teams were interviewed. The $Cmap_{pre}$ were transcribe to CmapTools and saved with file names allowing for easy identification (for example: "$Cmap_{pre}$ – Team 3 – 4A"), this process was performed by the Conéctate al Conocimiento facilitators. Having the Cmaps saved in CmapTools allowed for a more efficient manner of working when analyzing the Cmaps.

There was a one week interim between the construction of $Cmap_{pre}$ and the initialization of the Electrical Circuits project. The facilitator of Hagamos Ciencia project, Roberto Garrido, also gave his support. He is the person in charge of carrying out the inquiry experiences with the learner teams. Great stress was put into the

[4] *In fact, it has been programmed to apply this methodology in other schools in order to keep on improving the model and take advantage of the integration of two important Panamanian strategies: Conéctate al Conocimiento and Hagamos Ciencia..*
[5] *Taken from Learning How To Learn (Novak, Gowin)*
[6] *Parking lot of concepts used to build $Cmap_{pre}$: Electricity, battery, light bulb, wire, security rules, home electrical appliances, energy source, pile, electrocute.*

matter of keeping the teams for the inquiry experiences the same as the ones that built the $Cmap_{pre}$, aside from some variants; it was possible to keep some degree of control in this regard. After the 16 lessons from the project were covered (approximately 2 months later)[7] the Cmaps of the post experiences ($Cmap_{post}$) were built. The original conditions created during the construction of the $Cmap_{pre}$ were kept for the second session, the same teams, the same focus question, the same time was given, and the mediation kept on being only on translation on the part of the 4 facilitators. The main difference in the case of the $Cmap_{post}$ construction was that it didn't began with a blank page, the learners were given the $Cmap_{pre}$ and asked that, based on all that they had learned in the Electrical Circuit project, they make modifications to the ideas already stated on the $Cmap_{pre}$. Essentially what was done was a re-working up of the Cmap and a contrast between previous knowledge and new learning.

3 Results/ Analysis of $Cmap_{pre}$ versus $Cmap_{post}$

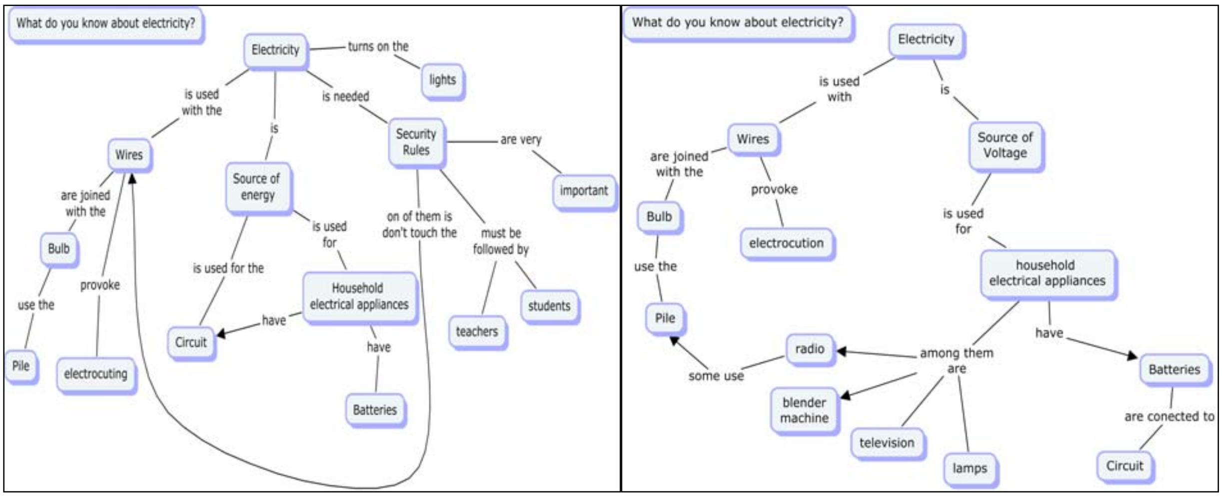


Figure 4: Example of $Cmap_{pre}$ and $Cmap_{post}$ built by a group of learners, they show some previous ideas they had about the question addressed.

3.1 *Treatment by sets of propositions*

We defined a set, denoted $\{Cmap_{pre}\}$, composed by all propositions generated in all of the $Cmap_{pre}$ and a corresponding set, $\{Cmap_{post}\}$, made up of all propositions generated in all of the $Cmap_{post}$. This allowed us to follow the evolution of the propositions. With the help of CmapTools, propositions were exported as text (properly identified), and transferred to a spread sheet which would help recognize, classify and filter the propositions. Propositions were classified in two categories: "deep" (d) and "superficial" (s) propositions.[8]

Table 1 shows the results obtained for the sets $\{Cmap_{pre}\}$ and $\{Cmap_{post}\}$.

Set	Total generated	Deep propositions	Superficial propositions	Percantage of Deep propositions	Percentage of Superficial propositions
$\{Cmap_{pre}\}$	288	89	199	30,9%	69,1%
$\{Cmap_{post}\}$	251	101	150	40,2%	59,8%

Table 1. Total number of propositions generated, deep propositions, superficial propositions, and percentages of each of these relative to the total generated. Sample included 15 $Cmap_{pre}$ and 15 $Cmap_{post}$

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[7] *During the time the experiences were carried out, some 2 lessons per week, the learners kept on receiving their regular classes, during which the teachers kept on reinforcing the construction of Cmaps.*

[8] Criteria used to determine "depth" of propositions are the following:

a) Proposition seek causes or effects in the relationship between concepts.
b) Proposition not limited to describing or enumerating concept attributes.
c) Proposition highly relevant and explicative within the context of the Cmap (in this case, electrical circuits).

Propositions that do not comply with all of the above, are considered "superficial."

As the table makes plain, these results indicate a greater proportions of superficial propositions for both sets of Cmaps. Nonetheless, there is a decrease in the second map relative to the first, and this decrease is significant (P = 0.02).

Among the 288 propositions in {$Cmap_{pre}$} and the 251 in {$Cmap_{post}$}, however, there were repeated propositions. In order to have a clearer picture of what actually took place in the group as a whole, it was necessary to identify repetitions, that is, propositions that are either identical or equivalent to one another. We found that the percentages of repeated propositions relative to the total number of generated propositions were 88.5% in {$Cmap_{pre}$} and 90.0% in {$Cmap_{post}$}. The percentages were not significantly different. Doing this helped us interpret what kinds of propositions are repeated in greater percentage by the teams, in terms of deep and superficial propositions. Our results are given in table 2.

Set	Total repeated propositions	Deep repeated propositions	Superficial repeated propositions	Total distinct propositions	Deep distinct propositions	Superficial distinct propositions
{$Cmap_{pre}$}	255	75	180	33	14	19
{$Cmap_{post}$}	226	85	141	25	16	9

Tabla 2. Indicates the total number of repeated and distinct propositions, as well as the number of deep and superficial propositions in each subset.

As can be seen, overall there were many repetitions (this was to be expected, to a certain extent, given that all Cmaps dealt with the same topic), 255 in {$Cmap_{pre}$} and 226 in {$Cmap_{post}$}. The following table shows the values in the form of percentages.

Percentage of deep repeated propositions in {$Cmap_{pre}$}	Percentage of deep repeated propositions in {$Cmap_{post}$}	Difference	Percentage of superficial repeated propositions in {$Cmap_{pre}$}	Percentage of superficial repeated propositions in {$Cmap_{post}$}	Difference
29,4%	37,6%	8,2%	70,6%	62,4%	-8,2%

Tabla 3. Percentages of deep and superficial propositions among subset of repeated propositions in {$Cmap_{pre}$}and {$Cmap_{post}$}.

Clearly, the percentages of superficial propositions were greater in both {$Cmap_{pre}$}and {$Cmap_{post}$}. However, we note that the percentage of deep propositions increased from {$Cmap_{pre}$} to {$Cmap_{post}$}, with a corresponding decrease for superficial propositions. Neither of these changes turned out to be statistically significant.

3.2 Analysis of "condensed Cmaps"

In what follows we define two subsets of {$Cmap_{pre}$} consisting only of distinct propositions of initial and final Cmaps. These sets will be designated {S_{pre}} and {S_{post}}, respectively. We refer to these subsets as the "condensed Cmaps," since they are made up of all distinct propositions from {$Cmap_{pre}$} to {$Cmap_{post}$}; these all repetitions have been eliminated. Thus, {S_{pre}} is the condensed $Cmap_{pre}$ while {S_{post}} is the condensed $Cmap_{post}$. It follows from table 2 that these maps are formed by 33 and 25 propositions, respectively. In table 4 we report the percentages of deep propositions in {S_{pre}} and {S_{post}}, respectively. This difference does turn out to be significant at 10% (P = 0.10)

Percentage of deep propositions in {S_{pre}}	Percentage of deep propositions in {S_{post}}	Difference
42,4%	**64,0%**	**21,6%**

Table 4. Comparison of percentages of deep propositions in {S_{pre}} and {S_{post}}.

4 Discussion

4.1 Of the results

In this study, entire sets of Cmaps needed to be handled and analyzed, in such a way that would reflect, quantitatively, whether there had been any changes subsequent to the project's activities. For this reason, an entirely new analysis methodology had to be developed (this was, in fact, the main purpose of the study) These new mechanisms, however, require validation, for it is not clear whether they constitute a valid way of determining the learning that took place among the students participating in the *Hagamos Ciencia* Project. This remark applies equally to the criteria we chose to determine the depth of a proposition. Having made this caveat, we proceed to discuss the implications of our results.

Our results indicate that among the total of propositions generated, superficial propositions predominated in both Cmaps (69,1% and 59,8% versus 30,9% and 40,2%). However, the change in the percentage of deep (and superficial) propositions between the initial and final Cmaps was significant. We believe this may have been a consequence of the inquiry activities carried out by the students. However, in training the students to use concept maps, we spent much time emphasizing rigorous thinking in order to construct propositions. Thus it is also possible that in some measure concept mapping may have contributed to the increase of deep propositions observed between the two Cmaps.

Another interesting result was that the 15 teams participating in the study coincided in (repeated) a large percentage of their propositions, both in the initial (88,5%) and the final (90,0%). (These values were not significantly different.) In a sense, this is not entirely surprising, since the subject matter was the same for all teams. More important is to notice that the percentages of deep and superficial propositions among the subset of repeated propositions were practically identical as the percentages in the complete set of propositions.

In spite of the fact that one cannot assure that a condensed map accurately reflects the joint knowledge of the teams, it is nonetheless a first approximation to an evaluation of a group of concept maps, which attempts to project itself as the group's collective knowledge. Clearly, it is necessary to validate the use of this form of condensed maps as truly reflecting group knowledge.

In considering the two condensed Cmaps, that is, the maps composed of the 33 and 25 distinct propositions from $\{Cmap_{pre}\}$ and $\{Cmap_{post}\}$, respectively, we focused our attention on the percentages of deep propositions. These changed from 42,4% and 64,0%, which is a significant change at 10% (P = 0,10). Once again, these values may reflect an impact of the *Hagamos Ciencia* activities in the students' knowledge. At the same time, the fact that concept maps were used to measure this knowledge, and that in training students in concept mapping, facilitators required students to think carefully and analyze various topics, we can not ignore the possible influence of this methodology upon the students.

4.2 Of the inconveniences:

Among the limitations that can be pointed out during the implementation of the model there are:
- The teachers had preconceptions about the Cmaps very different from the ones proposed by Conéctate al Conocimiento (Miller, 2006) that is, they didn't know about the construction of Cmaps based in propositions, nor the reasons why building them in this manner provide for knowledge representation and construction.
- The little time allowed for the person-to-person training. This happened because the teachers could not stop their daily educational activities, so the spaces to reinforce the training were very limited.
- The indiscipline in the groups of learners at the start of the sessions. This particular school is located within a community that presents several social problems which have a direct effect on the learners' behaviour and attitude. However, notwithstanding the issue just presented, the apprentices were enthusiastic enough with the project that the indiscipline lowered.
- The excessive time that passed between the reinforcing sessions and the construction of the Cmaps mediated by facilitators from Conéctate al Conocimiento. It was very difficult to stay close to the learners during the process. This task was entrusted to the school teachers, who should continue the training process with the learners.
- The issue that the interviews could not be used as a reliable source for contrasting the Cmaps, this was due to the lack of training in performing interviews.

5 Conclusion

This article presents a novel methodology, based on concept maps, for evaluating the acquisition of collective knowledge in science by a group of students working in teams, in the context of a scientific inquiry school project. Our results suggest that the model may be useful for determining group knowledge acquisition. However, based on our experience, several aspects of its implementation need improving, such as, adequate utilization of interviews, and the making sure that concept maps truly represent the state of learners' knowledge. Moreover, the model of data analysis requires validation; further studies need to be conducted to establish its validity.

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